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RESEARCH ARTICLE

Motion Sickness Susceptibility Among Malaysians When Travelling in a Moving Vehicle

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ABSTRACT - Motion sickness is a common problem when travelling in a moving vehicle, especially on land transportation. This occurrence would signify when users are exposed to unexpected movement in an obstructed view. Each user can experience a different level of motion sickness, depending on their susceptibility. This paper aims to study the motion sickness susceptibility among Malaysians using Motion Sickness Susceptibility Questionnaires (MSSQ-Short). A total of 252 Malaysians (146 males and 106 females) completed a set of questionnaires. The questionnaire was distributed through electronic means such as Facebook, WhatsApp, Twitter, and email and consisted of demographic, MSSQ-Short, travel experience as a driver and passenger, and seating position. This study provides a correlation between experiencing motion sickness between childhood and adulthood ($r = 0.124$, $p < 0.05$) for the Malaysian sample. This study concludes that Malaysian susceptibility is higher compared to other countries.

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1.0 INTRODUCTION

In the future, autonomous vehicle (AVs) is predicted to be available on the streets for consumers. AV is a product of the automobile industry's deep integration with artificial intelligence, which consists of high-performance computing and other new-generation information technologies. It is expected to revolutionise mobility systems in the near future [1]. The fast development shows that consumer demand keeps increasing since it minimises the need for human input and provides numerous benefits, such as more efficient traffic operations, self-parking patterns, and productive in-vehicle time utilisation [2]–[4]. The AV interacts with other people in a traffic environment, including pedestrians, cyclists, and other manually driven cars or motors [5]. Therefore, the sophisticated software added to the AV prevents the user from getting into a mishap. Another advantage of owning an AV is the ability to perform additional tasks, such as watching videos, reading books, working on a laptop, and playing phone games [6]–[9]. However, riding in an AV is known to induce motion sickness symptoms [9].

Motion sickness has been a common occurrence in people's daily life. It can happen in various situations, including when travelling in a car, a bus, a train or an aeroplane, riding on a funfair ride, or playing swing on a playground. Motion sickness can be characterised by symptoms such as increased body temperature, perspiration, sleepiness, nausea, dizziness, and other physical discomforts [10], [11]. This displeasing sensation usually happens when our body is exposed to a low-frequency acceleration, which is common in modern modes of transportation either by land, sea or air vehicles [10], [12]. The symptom can also appear while driving an autonomous vehicle because the driver is not in control of the vehicle, is not facing the direction in which it is moving, and is not able to see clearly in front of the vehicle because displays or the design of the vehicle are blocking their view [9]. It also can be caused by a sensory conflict between information from the human body's visual, vestibular, and somatosensory systems [10], [13], [14]. Other factors may affect someone's susceptibility to motion sickness, and previous research has found that while age has no bearing, gender can [12], [15].

When quantifying motion sickness, most researchers separated it into two categories: objective and subjective measurement [16], [17]. Through a subjective perspective, there is the Motion Sickness Susceptibility Questionnaire [12], [15], [18], Motion Sickness Assessment Questionnaire [19], and Misery Scale [4], [20]. MSSQ is used to determine and classify the respondent's motion sickness susceptibility, while MSAQ measures the level of experienced motion sickness during pre- and post-experiment [21]. MISC is usually used to assess the level of motion sickness during an experiment at a different set time interval. However, subjective measurement relies on assumptions, beliefs, and opinions and is influenced by emotions and personal feelings [22]. On the other hand, objective measurement (or continuous measurement) can be implemented to avoid or minimise any biases in subjective measurement. An example of continuous measurement is measuring acceleration using an accelerometer sensor. A moving vehicle's induced acceleration

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correlates with motion symptoms, especially a motion below 0.5 Hz [23]. Motion Sickness Dose Value is one of the calculations to derive how severe a motion can expose one to motion sickness acceleration [23], [24]. Physiological measurements such as heart rate can determine a motion sickness level [25], [26]. This study was conducted because the majority of studies are based in their own country [27]–[31], and there is not much knowledge on Malaysian susceptibility to motion sickness. Since Malaysians have a different demography than those in other studies, the data may also be different. The fact that Malaysia already permits autonomous driving on the roads and that Tesla has introduced an autonomous vehicle to the country's automotive market this year suggests that this study may also be useful [32], [33]. This paper aims to evaluate the pattern of motion sickness susceptibility among Malaysians, including any correlation between motion sickness and gender, driving license availability, preferred seat location, and distance travelled as passenger and driver, and compare it with other studies [12],[15].

2.0 METHODOLOGY

2.1 Procedure

In this study, the data is collected from respondents to measure their experiences of motion sickness and determine their susceptibility to it. The Motion Sickness Susceptibility Questionnaire (MSSQ) [15] is used in this study (cited by 406 papers according to Google Scholar) and distributed among Malaysians by electronic means such as Facebook, WhatsApp, Twitter, and email. The questionnaire also consists of other questions such as the driver's license availability, the average distance travelled per year as a driver and passenger, and the preferred seat location as a passenger in a car. The seats are classified as the front seat and back seat only (in Figure 1). The front seats are categorised as seats with visible front views, while the back seats are categorised as seats with obstructed front views [9].

Figure 1. Car seat arrangement

Figure 2 depicts the entire process flow of the study. Getting information and data on motion sickness is the initial stage in the process flow. The questionnaire consists of three categories, namely Motion Sickness Susceptibility Questionnaire (MSSQ), demography (age and gender), and driving or passenger experience in a car. The questionnaire was initially converted to a Google Form to save the information online. A power analysis test is conducted with an 85% confidence level during the data collection to ensure the data is adequate and meets the requirements. The questionnaire was re-distributed to obtain additional respondents if the sample size did not meet the requirements (about 208 sample size is needed in our study) or if the data obtained was not sufficient to run an analysis. Statistical analysis was performed after the necessary data had been collected. The results of the data analysis will then be assessed.

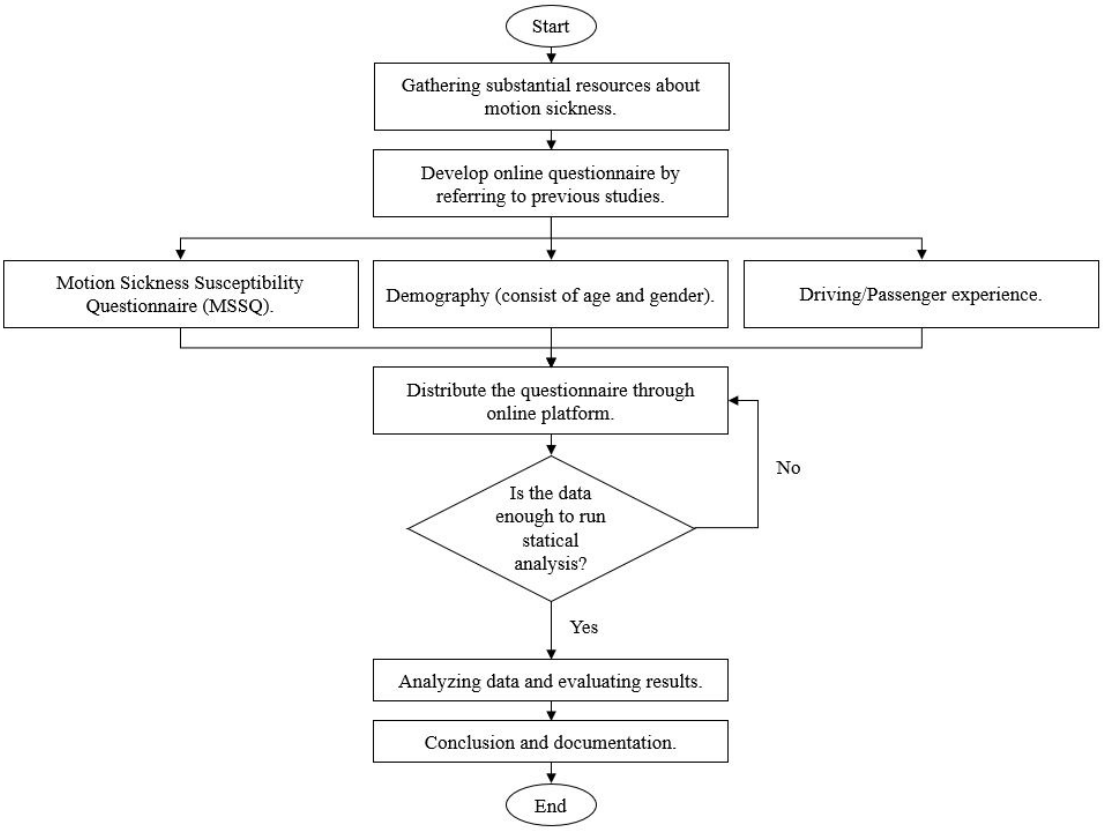

Figure 2. Study process flow

2.2 Motion Sickness Susceptibility Questionnaire (MSSQ)

The original MSSQ containing 54 items was developed by Golding [18]. However, the shorter version of the questionnaire, which consists of 18 items, was used after it was validated by the same researcher [15]. The MSSQ consists of two parts that require the respondents to fill up the questionnaire regarding their previous experience of motion sickness when travelling in a car, a bus, a train or an aeroplane, riding on a funfair ride, or playing swing on a playground. The first part is about the history of experiencing motion sickness as a child (before age 12), and the second part as an adult (for the past ten years) is labelled on a different rating scale from 0 (never felt sick) to 3 (frequently felt sick). Before converting it into a Google Form, the original questionnaire is shown in Figure 3.

The MSSQ scores are formulated from [15] as follows:

$$MSA = \frac{total\ sickness\ score\ child\ \times\ 9}{9 - number\ of\ types\ not\ experienced\ as\ a\ child} \tag{1}$$

$$MSB = \frac{total\ sickness\ score\ child\ \times\ 9}{9 - number\ of\ types\ not\ experienced\ as\ a\ child} \tag{2}$$

$$MSSQ\ raw\ score = MSA + MSB \tag{3}$$

Based on the MSSQ raw score, an estimation of MSSQ percentile rating y is used to classify how susceptible a person is to motion sickness either using a polynomial calculation with x, the MSSQ raw score, and a = 5.11609, b = -0.05517, c = -0.00068, d = -1.0717e^{-5}, or using a graph, as shown in Figure 4.

$$y = ax + bx^2 + cx^3 + dx^4 \tag{4}$$

This questionnaire is designed to find out how susceptible to motion sickness you are, and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting

Your childhood experience only (before 12 years of age), for each of the following types of transport or entertainment please indicate

1. **As a child (before age 12),** how often you **felt sick or nauseated** (tick boxes)

	Not Applicable - Never Traveled	Never Felt Sick	Rarely Felt Sick	Sometimes Felt Sick	Frequently Felt Sick
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3

Your experience over the last 10 years (approximately), for each of the following types of transport or entertainment please indicate

2. **Over the last 10 years,** how often you **felt sick or nauseated** (tick boxes)

	Not Applicable - Never Traveled	Never Felt Sick	Rarely Felt Sick	Sometimes Felt Sick	Frequently Felt Sick
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3

Figure 3. Motion sickness susceptibility questionnaire. Adapted from [15]

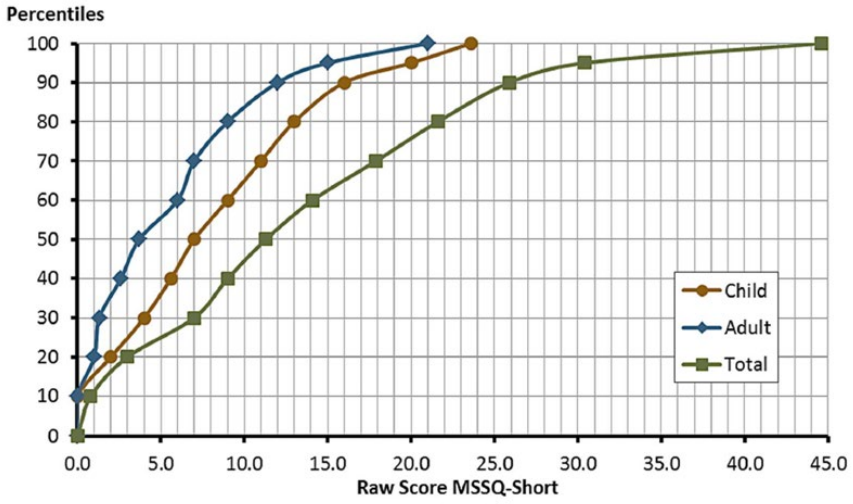

Figure 4. Percentile distribution of MSSQ raw score [15]

At first, Pearson's Correlation analysis was used to analyse the comparison of the MSSQ Score between the current study and the previous study [12], [15]. However, due to the non-linearity relationship when referring to the scatter plot

between the MSA and MSB, and it can be determined as a non-parametric correlation, a Spearman's Correlation analysis was conducted.

In addition, Point-biserial Correlation analysis was used to assess the relationship between MSSQ score and gender, driving license availability and preferred seat location. In this analysis, the p-value needs to be more than 0.05 to meet the assumption of homogeneity of variance and the normality test. However, only gender data meet both requirements (homogeneity of variance and normally distributed) in the analysis. Hence, a non-parametric correlation of Kendall's tau-b analysis was conducted for the driving license availability and preferred seat location data. Pearson's Correlation analysis was conducted for the correlation between MSSQ score; the distance travelled as a driver or passenger, and their driving license ownership period. However, all data have no linear relationship, so the analysis was changed to Spearman's Correlation.

3.0 RESULTS AND DISCUSSION

Two hundred eighty-one respondents aged between 17 and 66 years old completed the questionnaire. However, 29 respondents were identified as outliers due to bias. The bias was detected by observing the data with a similar score for all questionnaires. For example, a respondent answered only two questions in the questionnaire. Hence, only 252 have been selected to be included in the data. The respondents consist of males [n = 146 (57.94%)] and females [n = 106 (42.06%)] with a mean age of 27.55 years (standard deviation (SD) = 6.58).

3.1 Percentile Differentiation Analysis

Based on the MSSQ score, the median (50th percentile) score was 14.5, the 25th percentile was 10.0, the 75th percentile was 19.0, and the maximum percentile was 34.0. The 6-order polynomial closely approximates a percentile conversion: $y = -0.000006x^6 + 0.0002x^5 - 0.009x^4 + 0.1829x^3 - 1.5247x^2 + 7.3286x - 6.0681$. Figure 5 illustrates the percentile distribution of MSSQ raw scores among Malaysians, while Table 1 compares each quartile between the current study and previous studies [12], [15].

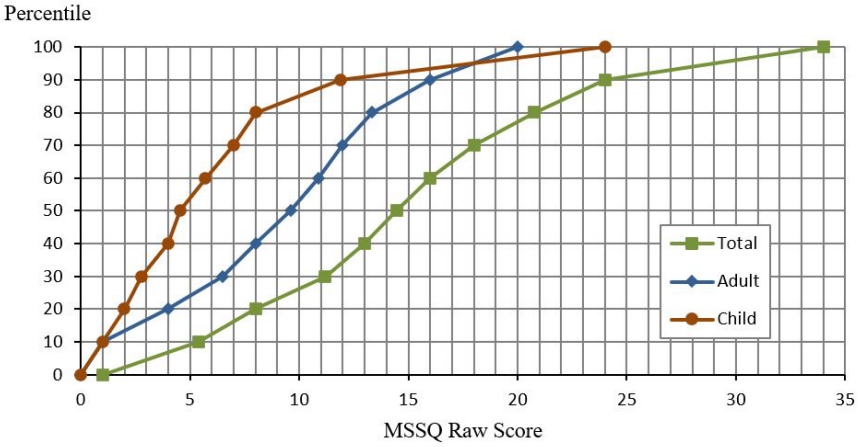

Figure 5. Percentile distribution of MSSQ raw score among Malaysians

Table 1 shows the percentiles of MSSQ scores for each study. The 25th and 75th percentiles represent the 1st and 3rd quartiles of the MSSQ score, while the 50th percentile is the 2nd quartile or median of the MSSQ score. The mean score for the current study is between the previous studies, which is 2.4 lower than [12] and 1.6 higher than [15]. At the 25th percentile, this study has the highest score of 10.0. This finding shows that Malaysians in a moving vehicle have higher chances of getting mild motion sickness (MSSQ score around 11 to 14 [34]) in the first quartile compared to other countries. At the 50th percentile (median) and 75th percentile, the MSSQ score is similar to other countries. This finding shows that half of the Malaysian and other countries are moderately susceptible to motion sickness. However, in the 100th percentile, Malaysians are less susceptible to motion sickness than in other studies. The dissimilarities in the distribution of MSSQ scores could be due to cultural and dietary differences in each country.

Table 1. Comparison of each percentile between the current study and previous studies

Variable	MSSQ score		
	Current study	Reference [12]	Reference [15]
Mean (SD)	14.5(6.9)	16.9(11.8)	12.9(9.9)
25th Percentile	10.0	7.0	5.0
50th Percentile	14.5	15.8	11.3
75th Percentile	19.0	25.0	19.0
100th Percentile	34.0	n/a	44.6*

*based on Figure 4

3.2 Percentile Differentiation Between Gender

The percentile differences between men and women are displayed in Figure 6. Each percentile shows how susceptible each respondent is to motion sickness. The severity of the susceptibility to motion sickness increases with percentile. Females are more susceptible to motion sickness than males in the other percentile but less susceptible than males in the first percentile. This finding is consistent with most research [35]–[40]. Females may also be more susceptible to motion sickness because of their smaller body stature, which includes a smaller body shape and smaller feet, thus reducing their sense of stability [41]. Their increased susceptibility to motion sickness may be caused by an increase in oestrogen levels, which frequently happens during the menstrual cycle or the initial month of pregnancy.

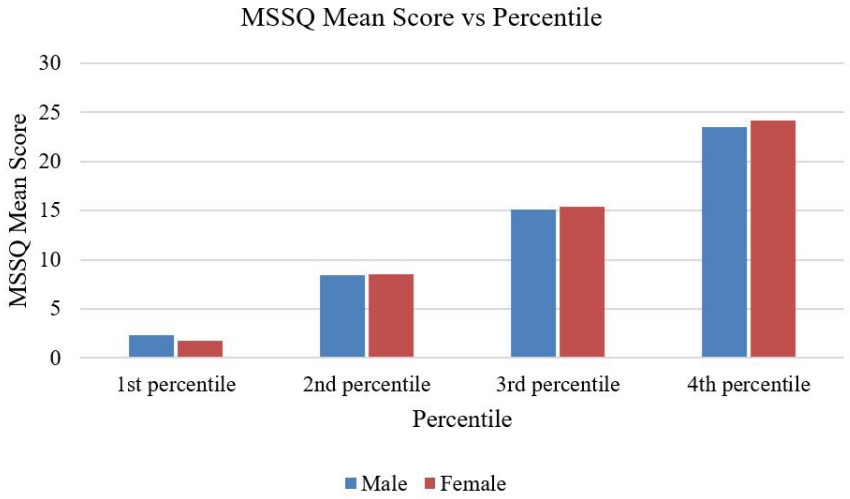

Figure 6. Percentile differentiation between genders

3.3 Characteristic Comparison

The correlation between motion sickness experience as a child (MSA) and motion sickness experience as an adult (MSB) and MSSQ score was analysed. Some of the analysed data were compared with previous studies [12], [15] in finding the differences in motion sickness experience between Malaysian and other countries. Table 2 represents the data of several characteristics for the current study and previous studies. Both previous studies have higher values of reliability (Cronbach's alpha), which are 0.91 and 0.87, respectively, while the current study is 0.76. This value indicates an acceptable level of internal consistency for the MSSQ scale. The comparison between studies shows that the current study's correlation between MSA and MSB is weaker but has a higher significance value. After referring to Spearman's correlation, it can be said that the correlation for the current study is statistically significant ($p < 0.05$). The correlation also might be affected by the respondent's age and gender since the current study has a lower median age and a higher number of males. The mean age for the current study is 12.85 years younger than [12] but 1.55 years older than [15]. Compared to Table 1, in the 75th percentile, it can be summarised that older people are more susceptible to motion sickness. This result is similar to the [42] findings. In addition, the higher number of female respondents in [8] supports the evidence that they have also been found to be more susceptible to motion sickness than men [43], [44].

Table 2. Characteristics of the current study compared to previous studies

Variable	MSSQ Score		
	Current study	Reference [12]	Reference [15]
No. of Respondents	252	1711	257
Males	146	798	94
Females	106	898	163
Mean Age (SD)	27.55(6.58)	40.40(13.10)	26.00(7.50)
Median Age	26	37	-
MSSQ Score Reliability Cronbach's alpha	0.76	0.91	0.87
Correlation MSA with MSB	0.12*	0.74**	0.68**
MSSQ = Motion Sickness Susceptibility Questionnaire; MSA = child score; MSB = adult score			
*p < 0.05; **p < 0.001			

3.4 MSSQ Score for Different Groups of Age

This group of age has been referred to [45]. The first group is categorised as early working age, the second is prime working age, the third is mature working age, and the last is elderly. Children (0 – 14 years old) are omitted since no

respondent is younger than 14 years old (the youngest is 17 years old, and the oldest is 66 years old). The standard deviation value decreases for each age group from 7.29 to 6.82 and drastically to 1.54. The standard deviation for 65 years old and above cannot be calculated since only one respondent is in the current study.

According to Table 3, more than 90% of the respondents are in the first and second groups, and the mean MSSQ score is around 14 (mild susceptibility to motion sickness [34]). This finding shows that almost all Malaysians are exposed to mild motion sickness in a moving vehicle. However, these findings should be interpreted with caution since the number of respondents can be considered low to represent the Malaysian population (about 32.7 million in July 2022 [46]). Additionally, Table 3 indicates the mean score increases with respondent age. The vestibular system becomes less effective with age, making it less able to respond and have a slower reaction time to head motion or other movements that typically cause inner ear imbalances [47], [48]. This could explain why the score on the Motion Sickness Susceptibility Questionnaire has increased.

Table 3. Mean and standard deviation for each age's group

Age (years old)	No. of respondents	Mean	SD
15 - 24	57 (22.62%)	14.26	7.29
25 - 54	191 (75.69%)	14.52	6.82
55 - 64	3 (1.19%)	17.78	1.54
65 and over	1 (0.40%)	24.00	-

3.5 Correlation Between Gender, Driving License and Preferred Seat Location

Based on the homogeneity of variance test, the p-value needs to be more than 0.05 to meet the assumption of variance, which is fulfilled by the gender and driving license data availability except for preferred seat location (Table 4). Hence, Kendall's tau-b analysis is conducted to correlate the preferred seat location data. Next, the test of normality was conducted to determine whether both the gender and driving license data are normally distributed (p-value > 0.05) or not. For gender, both male and female data are normally distributed, but not the holder's driving license data. Since this data is identified as not normally distributed, Kendall's tau-b analysis was conducted to assess the correlation with the MSSQ score by differences in a p-value of "Yes" and "No". Since the p-value of "Yes" is lower than "No", the correlation is statistically significant for the respondents with a driving license.

Table 4. Correlation of MSSQ score between gender, driving license availability and preferred seat

Variable	Gender		Driving license		Preferred seat location	
	Male	Female	Yes	No	Front	Back
No. of Respondents	146	106	227	25	179	73
p-value[1]	0.123		0.723		0.004*	
p-value[2]	0.301	0.249	0.017*	0.577	0.088	0.050
Correlation with MSSQ score	0.033(0.600)[3]		0.029(0.575)[4]		0.081(0.121)[4]	

[1]Test of Homogeneity of Variance; [2]Test of Normality; [3]Point-biserial Correlation; [4]Kendall's tau-b

*$p < 0.05$

There was no statistically significant correlation between the MSSQ score and all variables (gender, driving license, and preferred seat location). Furthermore, all correlations were found to have no effect (below 0.100). All Malaysians might have similar susceptibility to motion sickness regardless of their gender. Whether a respondent owns a driving license or not is unrelated to their susceptibility to motion sickness. However, in this study, only 25 out of 252 (9.92%) respondents do not possess a driving license. Hence, the finding might not be reliable. On the other hand, the result contradicts the other studies [49], [50] that stated sitting in the back seat has higher chances of getting motion sickness due to a blocked view of the road. This contradiction might show that Malaysian people might not get motion sickness at any seat in a moving vehicle. However, these findings should be interpreted cautiously due to the condition when sitting inside the car. The questionnaire did not specify any activities for the preferred seat location. When engaging in an activity, the possibility of exposure to motion sickness is higher compared to doing nothing or looking outside [9].

The line graphs for both genders across the age range are shown in Figure 7. The number of respondents may impact how much the line graph for male respondents declines in the second age group. There are 118 respondents in the second age group, compared to just 28 in the first. The first three age groups for female respondents show a steady increase in the line graph, while the fourth group declines to zero. It can be explained by the fact that none of the female respondents was over 65 years old. As both graphs increase, it can be concluded that as respondents age, their susceptibility to motion sickness increases for both genders.

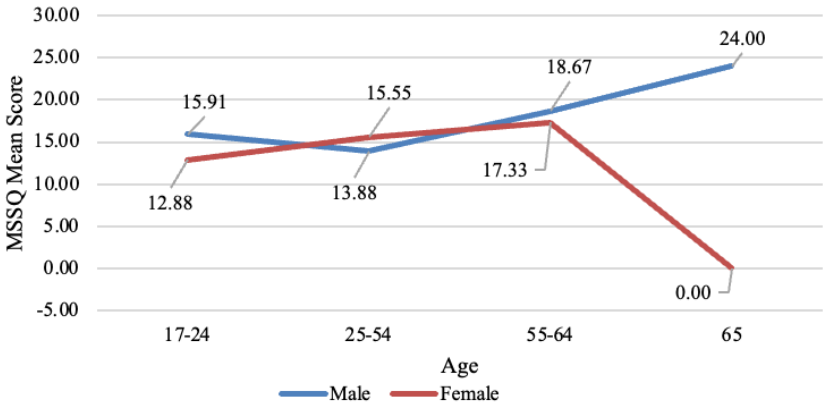

Figure 7. Gender respondents across the age group

3.6 Correlation for Distance Travelled as a Driver or as a Passenger

Spearman's correlation analysis assessed the correlation between the MSSQ score and the average distance travelled as a driver or a passenger (Table 5). There was no statistically significant correlation between the MSSQ score and both average distances travelled data. The average distance travelled as a driver has a correlation of 0.029, while the average distance travelled as a passenger is 0.089. Furthermore, both correlations were found to have no effect (below 0.100).

Table 5. Correlation of MSSQ score with average distance travelled as a driver or a passenger

Variable	Average distance travelled by driver (km/year)	Average distance travelled by passenger (km/year)
Correlation with MSSQ score (p-value)	0.029 (0.642)	0.089 (0.157)

4.0 CONCLUSIONS

Both previous studies, [12] and [15], have shown that each represented data varies but not many differences compared to the current study. Malaysian older people were more susceptible to motion sickness than other age groups. The percentile distribution of the MSSQ score is almost similar to the original study [15] except for the low maximum MSSQ score (Malaysian = 34.0, [15] = 44.6). Hence, this Malaysian percentile distribution of MSSQ scores can be used for future studies, especially when assessing Malaysians susceptible to motion sickness using MSSQ. This is crucial when designing the experiment involving participants with high and low susceptibility to motion sickness [51]–[53]. For future recommendations, the number of participants can be increased to obtain a higher percentage of confidence level after being evaluated in a power analysis test and to validate the findings.

5.0 ACKNOWLEDGEMENT

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